The "Global Drifter Program"
Drifter Measurements of Surface Velocity, SST, SSS, Winds and Atmospheric Pressure

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1. PROJECT SUMMARY

1.1. Rationale

The principal scientific questions of the role of the ocean in climate change are how well can we describe or model the ocean circulation today and how well can these descriptions or models predict the evolution of future climates. Climate time scale changes in the sea surface temperature (SST) directly force changes in the air temperature and habitability conditions very large parts of the globe. On these interannual time scales SST depends on ocean circulation as well as air-sea interaction. A global array of drifters provide the operational instrumental data sets describing SST and ocean near surface circulation and evolution and these data are used for testing climate models and enhancing long-range weather prediction and interannual climate change.

Sensors that measure sea surface salinity (SSS) are now added to drifters and these SSS data are critical to determining the oceans' fresh water cycle and onset of deep-water renewals. Air pressures measured on drifters are assimilated into weather prediction models and are used by operational meteorological agencies to discern severe weather conditions over the oceans. Drifter pressure data also contribute significantly to the calculation of the inverted barometer effect on global sea level rise as measured from altimeters. Wind sensor and subsurface temperature chain data are used to improve prediction of tropical storms and hurricanes. Drifters designed and built within the *"Global Drifter Program"* (*GDP*) have proven to be reliable, autonomous platforms for obtaining climate and operational weather data from the global oceans.

1.2. Objectives of the " Global Drifter Program"

The "*Global Drifter Program*" (*GDP*) is the principal international component of the Joint Commission of Marine Measurements (JCOMM) *"Global Surface Drifting Buoy Array"*. It is a "Scientific Project" of the Data Buoy Cooperation Panel (DBCP) of World Meteorological Organization (WMO)/International Ocean Commission (IOC). It is a near-operational ocean-observing network that, through the Argos satellite system and the Global Telecommunication System (GTS), returns real time data on ocean near-surface currents, SST and air pressure (and winds, subsurface temperature - T(z), and SSS) and provides a data processing system for scientific utilization of these data. In addition to *GDP*, drifters are deployed by operational oceanographic and meteorological agencies and individual scientific research projects, whose data are utilized by *GDP*. In turn, *GDP* data are made available to operational users and scientists at large. Wind-

sensors, salinity sensors and thermistor chains are added to SVP drifters, both on for specific operational and research requirements. The international protocols for these data exchanges and sensor additions are worked out each year by DBCP.

The scientific objectives of the *GDP*, and its operational and research partners, are:

1) Provide to GTS a near-operational, near-real time data stream of drifter position, SST, and sea level air pressure. GTS compatible data on winds, T(z) and SSS are also provided on operational basis when these sensors are mounted on the drifters.

2) Observe the 15m depth velocity on a global basis with 5.0° resolution and, jointly with satellite altimeter data, produce charts on the seasonal and interannual changing circulation of the world ocean at 0.5º resolution (Figure 1)

3) Develop and introduce into the drifter construction technological advances in sensors, electronics, power, methods of assembly and deployment packaging.

4) Provide enhanced research quality data sets of ocean circulation that include drifter data from individual research programs, historical data from instruments different from the Surface Velocity Program (SVP) Lagrangian Drifter and the corrected data sets for wind-produced slip of drifter velocity. To this end *GDP*:

- Provides to the coupled ocean-atmosphere climate modelers gridded, global data sets of SST, near surface circulation and dynamic topography for assimilation and the verification of the parametrized processes, such as wind-driven Ekman currents and spatial patterns of the seasonal circulation.
- Provides the Lagrangian data sets for the computation of single particle diffusivity, dispersal of ocean pollutants, the enhancement of models of fisheries recruitment and improvement of air-sea rescue.
- Obtains high-resolution coverage of ocean variability and time mean circulation in support of ENSO prediction model verification in the tropical Oceans and supports short-term research projects that require enhanced upper ocean velocity observations.

1.3. Required Drifter Observations and Status of Global Array

The 'required' global drifter array size by JCOMM is based on the need to maintain 1250 platforms that return instrumental observations of daily average SST (+/- 0.1^0C) over the global ocean at a 5º resolution, or the spatial scale of the error covariance function of the operational NOAA satellite infrared SST sensors (Figure 2). In the past 36 months the array has exceeded the 1250 required elements on more than half of the months, but more recently numbers have fallen below 1200. Surface pressure sensors are also supported by regional meteorological agencies based on regional needs, generally exceeding 500 elements. The number of drifters in the array is composed of the NOAA/*GDP* supported (85%), drifters deployed by principal investigators who have requested that their Argos Service costs be part of *GDP* contract. In turn, their data is included in the *GDP* real-time data that is placed on to the GTS. International oceanographic and meteorological agencies also deploy about 120 drifters per year.

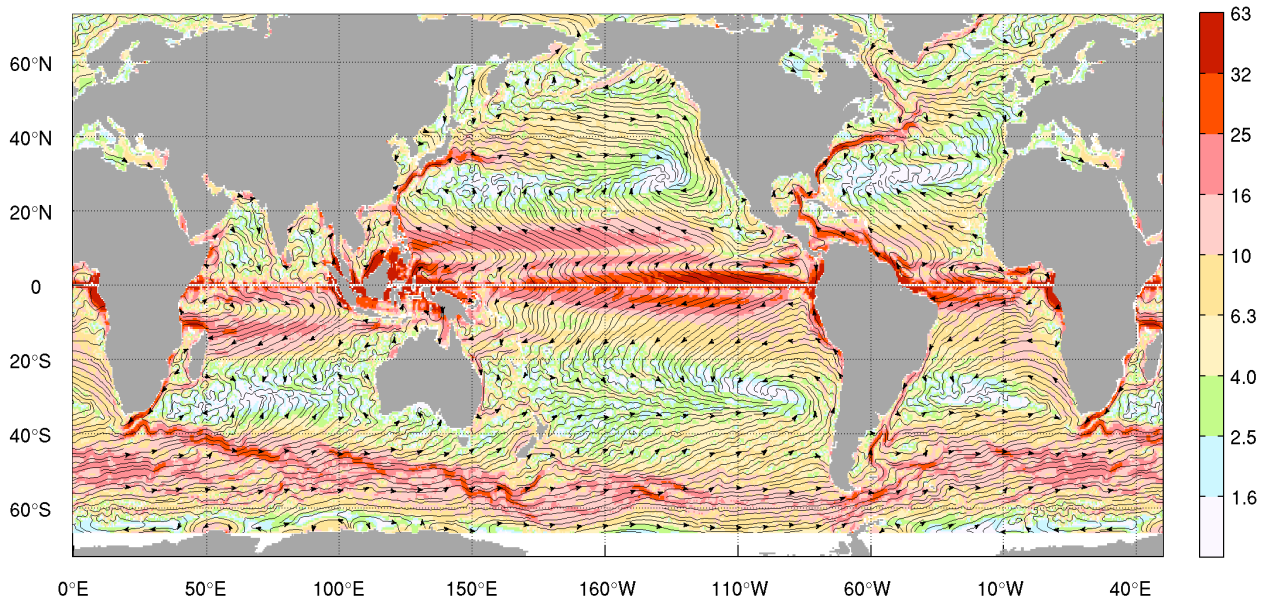

Figure 1. Mean streamlines calculated from a combination of drifter and satellite derived 15m-circulation at 0.50º resolution from data of October 1992 to December 2007. The choices of streamlines are made in an iterative fashion to cover the ocean at relatively uniform, several degree scale spatial density, giving the preference to the longest lines. Colors are magnitudes of the sum of the mean geostrophic plus Ekman velocity used to compute the streamlines, and units are cm/s. Note the "maelstroms" of circular convergent regions at 30ºN, 140ºW (a well known region of accumulation of plastic debris in the Northeast Pacific) and an heretofore unknown, but larger and more stable region at 30ºS, 90ºW.

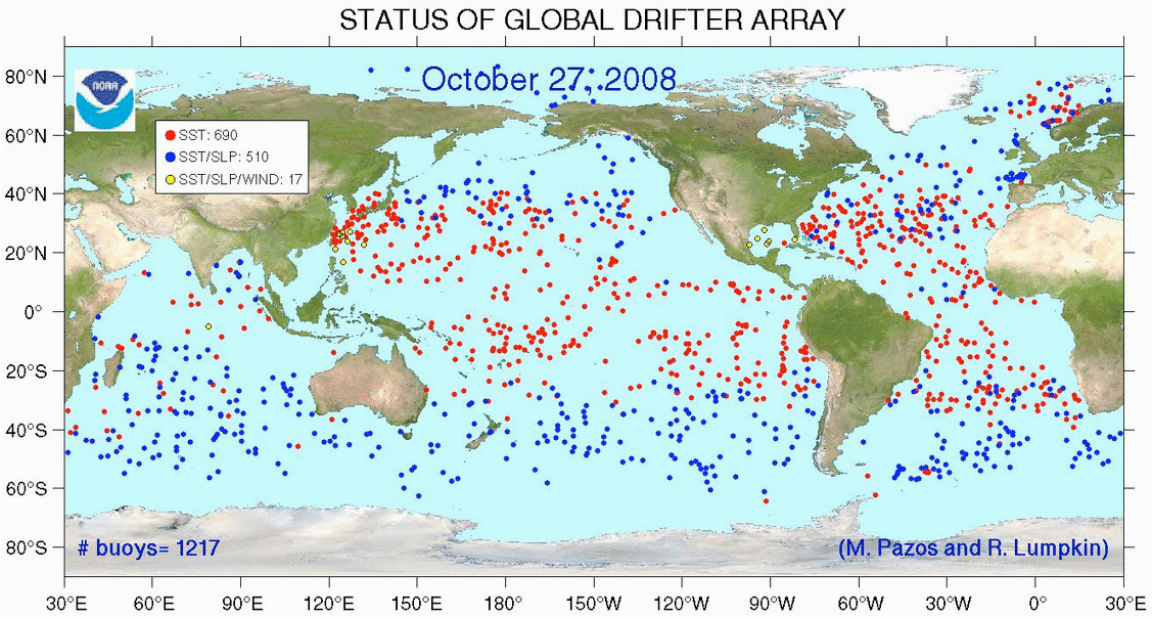

Figure 2. The JCOMM *Global Drifting Buoy Array* on October 13, 2008. Throughout the past 24 months the global array of SVP-B has exceeded 500.

On 27 October 2008, 1217 drifters were reporting to GTS and to the Atlantic Oceanographic and Meteorological Laboratory (AOML) *Drifter Data Center* (Figure 2). NOAA Climate Observations Program, funded to JIMO (910) and AOML (90) sufficient numbers of SVP drifters in FY'07, and with the contributions of drifters (100-120) from other national and international sources, the array was maintained from late 2005 to present date at a bit below the desired level. *GDP* /AOML is requesting additional drifters (143) to be funded to make up this gap.

1.4. Management

GDP reports every year on its activities relative to advances in technology in the DBCP "Technical Session" and its deployment plans and management in the DBCP "Plenary Session". *GDP* is managed according to the *"Ten Climate Monitoring Principles"* established by JCOMM. In these management tasks, the Principal Investigator of this proposal, Peter Niiler, assumes the responsibility for the coordination between the following entities:

• US manufacturers in private industry (*Technocean, Inc.* of Cape Coral, FL*; Clearwater, Inc*. of Watertown, MA*; Pacific Gyre, Inc.* of Oceanside, CA*)* who build the SVP, SVP-B, SVP-W and SVP-W-T(z) drifters according to closely monitored specifications. Internationally. Six private firms and several research laboratories build SVP drifters. Periodically, drifter construction manuals are upgraded and are posted on the DBCP website (e.g. 2005 the SVP-B Mini Construction Manual for which an upgrade is planned for 2009). As projected in the FY'09 budget, the price of the drifters, due to significant inflation in the past 18 month period, will be $100 per drifter more expensive than as these were in FY'08.

• Atlantic Oceanographic and Marine Laboratory (AOML) who carries out the deployments at sea, processes the data and archives these at MEDS, Canada, maintains the META file on the description of each drifter deployed and the maintains the *GDP* website.

• Technical staff of SIO, who assist in the supervision of aircraft deployments of drifters into hurricanes, place orders for the NOAA funded drifters, upgrade the technology, develop new sensors, enhance the data sets and maintain liaison with individual marine research programs that deploy SVP drifters.

• Supervision of cooperative arrangements with other NOAA and ONR, NSF and Internationally sponsored programs. *GDP* encourages principal investigators to purchase SVP – type drifters for their studies and make data from these drifters available on GTS to the international community. *GDP* also sends SVP drifters purchased by JIMO to be deployed in concert with the special projects to enhance the Lagrangian data sets.

This report from JIMO/*lGDP* addresses the progress of activities in FY'08 and proposes the activities for FY'09.

2. FY08 PROGRESS

In FY'08 NOAA Grants Office funding of the *GDP* through JIMO occurred in the third week of September 2008. This is a report of what was accomplished with both the FY'07 and FY'08 funding during the period of November 2007 – November 2008:

2.1. Summary of Drifter Acquisitions

With the FY'07 funds 910 drifters with SST sensors were manufactured and were delivered to AOML for deployment. With the FY'08 funds, 910 drifters were ordered in October 2008 and will be delivered to AOML for deployments during the calendar year 2009. With the FY'2008 funds, the composition of the drifter order in October 2008 to industry was:

a) A total of 620 SVP drifters were ordered from Clearwater Instruments, Inc Pacific Gyre, Inc. and Technocean, Inc. These are now being delivered to AOML for deployment.
b) A total of 270 SVP-B drifters were ordered from Clearwater Instruments, Inc., Technocean, Inc. and Pacific Gyre, Inc. These are now being delivered to AOML for deployment.
c) A total of 12 SVP-W wind-drifters (Minimet) and 8 SVP-W-T(z) wind and chain drifters (ADOS), fully rigged for air deployment, were ordered from Pacific Gyre, Inc. This is the third year that an industrial firm will build, calibrate and rig for air-deployment a full suite of hurricane drifters. All 20 units will be delivered the 53rd Air Force Reserve "Hurricane Hunter Squadron" at Keesler AFB before July

1, 2009. Dr. Rick Lumpkin and Dr. Eric Uhlhorn of AOML directing the design of the arrays that will be deployment for the 2009 Hurricane season.

In FY'08 JIMO has purchased 910 drifters and AOML purchased 140 drifters (from METOCEAN, Inc., Canada**), for total NOAA contribution of 1050 drifters to the JCOMM *"Global Surface Drifting Buoy Array".***

2.2. Sustained, Targeted Hurricane Deployments of Drifters

In 2008 Hurricane season targeted drifter deployments by the AF 53rd,Hurricane Hunter Squadron at Keesler AFB became fully operational. Ten training buoys and at least 20 operational drifters have been delivered by JIMO in years 2005, 2006, 2007 and 2008 to the 53rd. During this period, 75 of 77 deployed drifters provided data through Tropical Cyclone (TC) passages. The training buoys are used to maintain operational training exercises throughout the year for the 53rd flight crews for handling, storage, staging, loading and air-deployment of drifter packages.

Operationally, a drifter deployment plan is communicated from the National Hurricane Center/CARCAH in Miami to the 53rd Hurricane Hunter Squadron command at least 48 hours ahead of the expected deployment time. Final adjustments of the location of an array relative to the TC center are made 6 hours before the expected time of lift off of the 53rd C-130. In September 2008, successful operational deployments occurred in Hurricanes Gustav and Ike in the Gulf of Mexico (Figure 3).

With the assistance of ONR and NOAA/OAR, the combined *GDP* projects at JIMO and AOML have worked closely with the NHC and the AF 53rd Hurricane Hunter Squadron over the past five years to bring about a sustained ocean and atmosphere targeted observing system for Hurricanes and Typhoons. Crucial partners are also the US industrial firms of Pacific Gyre, Inc. and Clearwater Instruments, Inc. who build and maintain the store of drifters at Keesler AFB. This partnership is now sustained with funding of Minimet (SVP-W) and ADOS (SVVP-W-T) drifters through OCO/NOAA. In 2009 Hurricane season there will be 44 operational drifters stored in a Keesler AFB hangar.

2.3. Cooperative arrangements with ONR

In 2004 NOAA and ONR participated in a landmark study, CBLAST, of the effects of hurricanes on the ocean. With ONR continued support Jan Morzel (*Rosetta Consulting, Inc., Boulder CO*) has gathered all data acquired from dropsondes, drifters, floats, altimeters and scatterometers on to a website: http://tao-tc.ucsd.edu. ONR will continue to support this website for both hurricane and typhoon ocean data through 2011.

During the western Pacific Typhoon study, termed TCS-08, 24 *GDP* drifters were shipped to Andrews AFB in Guam, and under the direction of Mst.Stg.Rober E. Lee (retired) these were deployed in front of Typhoons Janghmi and Hagupit (23 of the 24 drifters that had been in storage for over 24 months deployed properly and produced data

through passages of these storms: viz. Figure 4). **The objective of this ONR/NOAA cooperation is to maintain an ocean-air data set that can easily be accessed by scientists who wish to use it for improvement of coupled numerical models of Tropical Cyclones. By June, 2009, data sets from 9 hurricanes and typhoons will be in place in uniform easily accessible formats.**

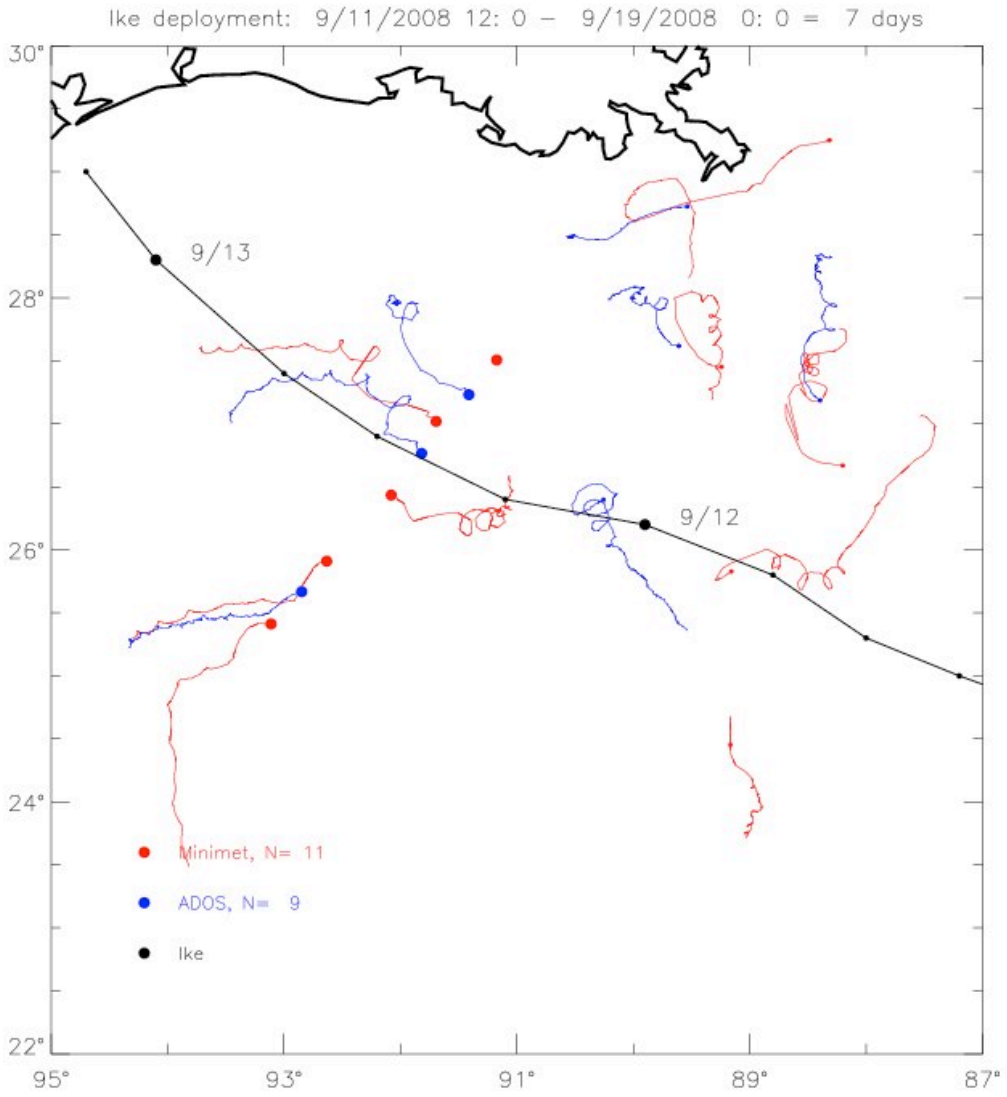

Figure 3. The drifter deployment pattern in front of Hurricane Ike in the Gulf of Mexico in September 2008 where red and blue dots mark the Minimet and ADOS drifter deployment locations. The red and blue lines are the subsequent 7-day tracks of drifters. Note that 9 drifters from the deployments in front of Gustav, 10 days before Ike, also observed the passage of Ike.

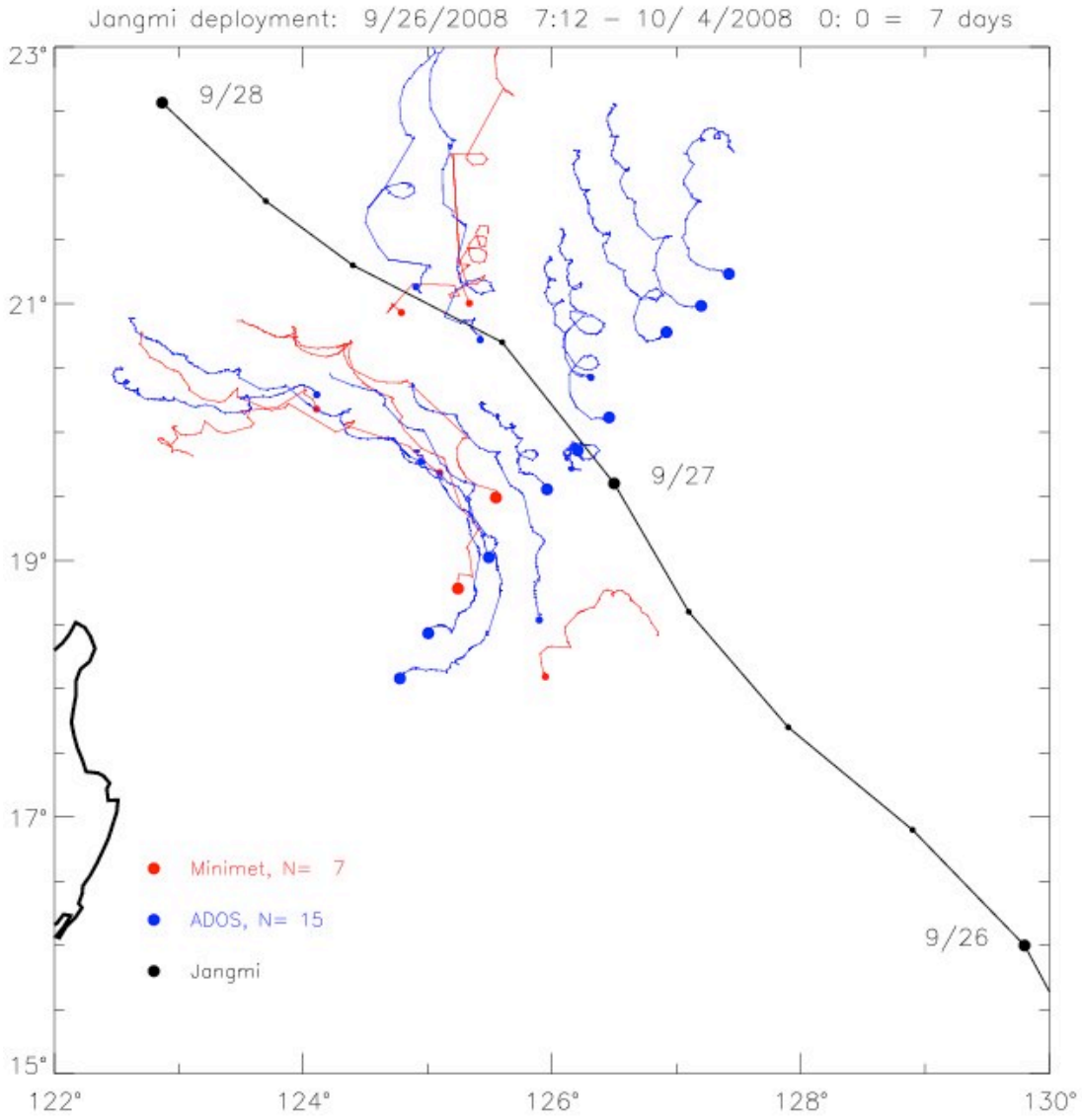

Figure 4. The drifter deployment pattern in front of Typhoon Jangmi in September 2008 in the western Pacific where red and blue dots mark the Minimet and ADOS drifter deployment locations. A total of 23 tracks appear because 12 drifters deployed in Typhoon Hagupit that passed over this region 6 days earlier were still sending good data.

2.4. Technical developments in drifter sensors

The temperature, air pressure wind direction and salinity sensors on drifters have worked reliable and produced data that has been possible to compare with other observations. The wind speed sensor, or WOTAN, that is based on ambient noise in the ocean cannot be interpreted in hurricane strength winds. In 2008, working with Pacific Gyre, Inc. we have installed a small Gill Acoustic Anemometer on the Minimet (SVP-W) and ADOS (SVP-W-TC) float (Figure 5). Calibration tests at sea are ongoing off San Diego during 11-15 November 2008 and we expect to place two of these drifters into the North Pacific in January 2009 for a longer deployment. These will be calibrated continuously with QSCAT over flight data.

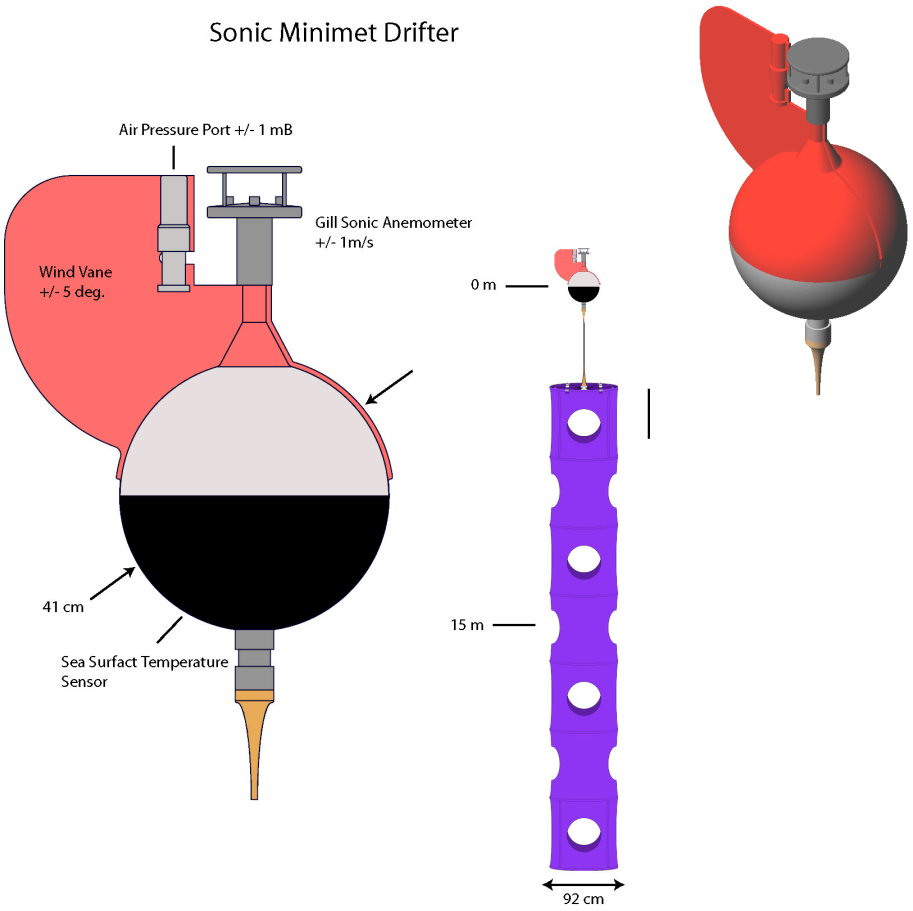

Figure 5. Schematics of the sonic Minimet drifter that is now in field tests off California next to NOAA/NDBC moored buoys. The digital controller within the surface float will integrate sample air pressure, tilt, compass direction and Gill anemometer wind speed at 1 sec intervals and record wind speed and direction measurements during conditions when the surface float is out of the water and level with the horizon. These conditionally sampled data will be averaged over 5 min periods once an hour and transmitted to Argos satellite system.

Two ADOS drifters that can be launched from a AXBT size hole in an aircraft fuselage have been assembled by Clearwanter Instruments, Inc. and tested in the laboratory conditions (viz: *GDP Report*, 2008 and Figure 6). We anticipate full at sea tests in early 2009.

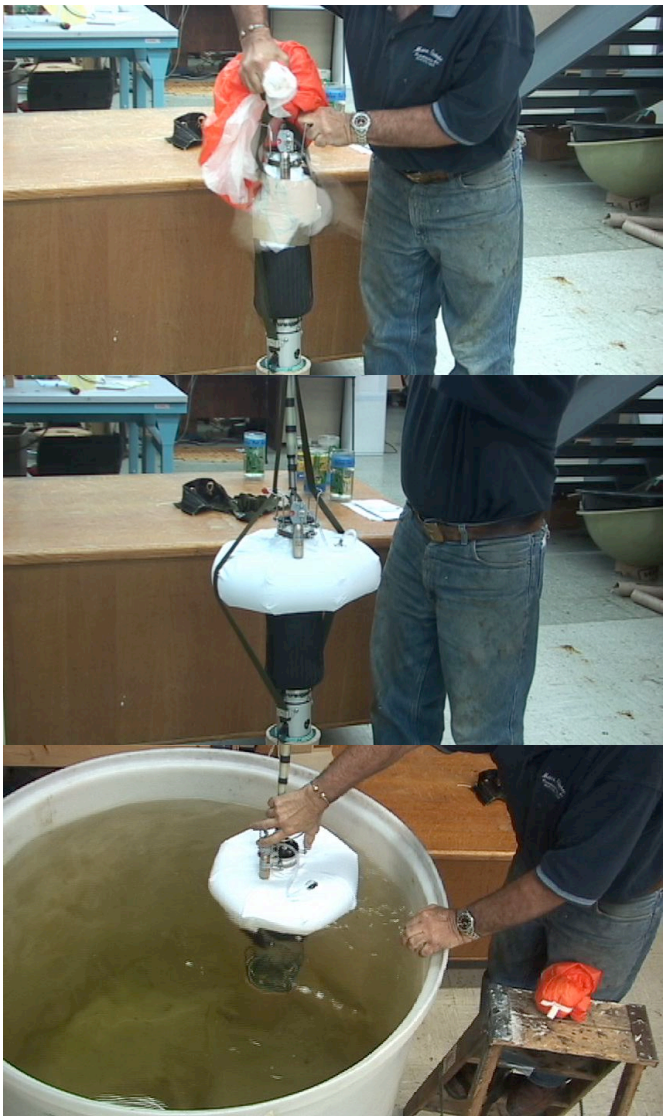

Figure 6. The sequence of laboratory photos showing the inflation of the floatation bladder for the ADOS drifter that is configured to be deployed from the AXBT launch holes in aircraft. A small parachute activates the inflation mechanism (note the orange and white cloth in upper panel). The bladder is a self-sealing inner tube that is used for ATVs and it is covered with fiber-enhanced sail cloth to prevent sea birds from puncturing the float. The entire ADOS drifter is packed in a cylindrical casing that is 4.5" in diameter and 36" long and automatically releases 150m of wire with 10 temperature and pressure sensors. At sea tests are planned for early 2009 off San Diego, CA. Releases from aircraft will occur in summer 2009.

2.5. Enhanced Data Sets and Publications:

Between December 2006 and November 2008, there were 25 requests for enhanced drifter velocity data sets. Dr. Yoo Yin Kim who works under the direction of P. Niiler as a Senior Statistician prepared and distributed these data. The drifter peer-reviewed publication list was upgraded in December 2006: (http://www.aoml.noaa.gov/phod/dac/drifter_bibliography.html).

2.6. Meetings and Lectures

The following SIO personnel participated in the GDP presented lectures or attended the following organization meetings:

• Invited Lecturer at the workshop on "First CLIVAR Global Synthesis and Observation Panel Workshop on Ocean Velocity Measurements and their Application" December 5-7, 2007,La Jolla, CA: "Drifter Technology and Surface Circulation" (Peter Niiler)

• Invited Lecturer at the Keelung National Ocean University, Taiwan, March 20, 2008: "Observing Tropical Cyclones with Drifting Buoys" (Peter Niiler)

• AMS Conference on Tropical Meteorology, Orlando, FL. May 2, 2008: Drifting buoy deployments into Hurricane Dean, 2007 (Rick Lumpkin , NOAA/AOML, Miami FL; and P. P. Niiler and P. Black)

• Invited Lecture, OCO Meeting in Silver Spring, MD, June 3, 2008: "New Ocean Circulation Patterns from Combined Drifter and Satellite Dataz' (Peter Niiler)

• DBCP-XXIV, October 15-19, 2008 Cape Town, South Africa: "Operational deployments of drifting buoys into targeted Tropical Cyclones" (Luca Centurioni, Peter Niiler and Rick Lumpkin)

• DBCP-XXIV, October 15-19, 2008 Cape Town, South Africa: "The Global Drifter Program" (Luca Centurioni for: Rick Lumpkin and Mayra Pazos)

• Invited Lecture at the AGU Fall 2008 Meeting, San Francisco, CA December 17, 2008: "Equatorial Pacific vorticity and thermal energy balances determined from Lagrangian drifter observations" (Peter Niiler)